

The Dimensionality Constraint: Why Spacetime Must Be 3+1 Dimensional

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Abstract

We argue that the 3+1 dimensionality of spacetime is not a contingent fact but a geometric necessity following from holographic encoding on event horizons. The event horizon of a black hole is necessarily a 2D surface (codimension-1 boundary in 3D space). From a 2D encoding surface, interior dimensions emerge as: (1) the two dimensions of the surface itself, which holographically encode three spatial dimensions; (2) one dimension from the inward direction of wormhole projections; and (3) one dimension from the sequence of transaction completions, which we experience as time. This yields exactly 3+1 dimensions—no more, no less. The dimensionality of physics is thus not a parameter to be explained anthropically but a structural consequence of how holographic encoding works. All black hole interiors, in any parent universe, must be 3+1 dimensional. What varies between universes is not dimensionality but scale (shell area), composition (frozen emission spectrum), and initial conditions (collapse dynamics).

1. Introduction

Why does spacetime have three spatial dimensions and one time dimension? This question has haunted physics since the recognition that other dimensionalities are mathematically conceivable. Various approaches have been tried:

Anthropic arguments: Only 3+1 dimensions permit stable atoms and planetary orbits, so observers can only exist in 3+1 dimensional universes.

String theory: Extra dimensions exist but are compactified at small scales, leaving an effective 3+1 dimensional physics.

Brute fact: Dimensionality is simply a given, not requiring explanation.

We propose a different answer: 3+1 dimensions are geometrically FORCED by the structure of holographic encoding on event horizons. If our universe exists within a black hole, as blitson cosmology suggests, then the dimensionality of our spacetime follows necessarily from the dimensionality of the encoding surface.

This transforms the question of dimensionality from a mystery requiring anthropic explanation to a theorem following from geometric premises.

2. The Encoding Surface Must Be 2D

2.1 Event Horizons as Boundaries

In general relativity, an event horizon is the boundary of a black hole—the surface beyond which events cannot causally influence the exterior. Mathematically, a boundary has codimension 1: it has one fewer dimension than the space it bounds.

For a black hole in a 3D spatial universe, the event horizon is 2D. This is not a choice or a simplification—it follows from the definition of a boundary. Any parent universe with 3D space will produce black holes with 2D horizons.

2.2 Holographic Encoding

The holographic principle, established through work on black hole thermodynamics, states that the maximum information content of a region is proportional to its boundary area, not its volume. The Bekenstein-Hawking entropy formula makes this precise:

$$S = A / 4\ell_P^2$$

where S is entropy (information), A is horizon area, and ℓ_P is the Planck length. The information about the interior is encoded on the 2D surface—approximately 10^{122} bits for a cosmological horizon.

2.3 Not a Choice

The 2D nature of the encoding surface is not a parameter we can vary. It is fixed by:

- (a) The geometry of boundaries (codimension-1)
- (b) The parent universe having 3D space
- (c) The holographic principle placing information on the boundary

A 1D encoding surface would result from a parent universe with 2D space—possible in principle but supporting far less complexity. A 3D encoding surface would require a parent universe with 4D space. In either case, the encoding surface dimensionality is determined by the parent, not chosen freely.

3. From 2D Surface to 4D Interior

3.1 Rethinking the Block Universe

The term "block universe" suggests a 4D solid with events distributed throughout. But this image is misleading. In the framework developed in previous papers, there is no 4D "block"—there are only:

- Endpoints (blitzons) on the 2D shell
- Wormholes (transactions) connecting endpoints
- Nothing else—no space "between," no time "in which"

The 4D spacetime we experience is not fundamental structure but EMERGENT—how we, as patterns in the wormhole network, perceive the topology of connections.

3.2 The Four Dimensions Identified

From a 2D encoding surface, exactly four dimensions emerge:

Dimension 1 & 2 — The Shell Itself: The 2D surface has two intrinsic dimensions. Blitzons have positions on this surface, defining a 2D geometry. Through holographic encoding, this 2D surface encodes 3D spatial information—this is the content of the holographic principle.

Dimension 3 — Inward Projection: The wormholes point INWARD—away from the shell, toward the interior. This is a direction not contained in the shell surface. It constitutes a third spatial dimension. The "depth" of a transaction—how far inward it reaches—corresponds to position along this dimension.

Dimension 4 — Transaction Completion (Time): The frozen emissions on the shell are incomplete transactions seeking completion. The SEQUENCE of virtual connections becoming real completions defines a direction we experience as time. This is not a spatial direction but an ordering—the cascade of transactions completing, each enabling subsequent completions.

3.3 The Count Is Exact

We get exactly four dimensions because:

2 dimensions: the shell surface
+ 1 dimension: the inward direction
+ 1 dimension: the completion sequence
= 4 dimensions total (3 space + 1 time)

There is no room for a fifth dimension. The shell has only 2D; inward is only 1D; completion sequence is only 1D. No other geometric element exists from which additional dimensions could emerge.

There is no way to have fewer dimensions. Removing any element would mean either: no shell (no encoding), no inward direction (no interior), or no completion (no time). Each is essential.

4. The $S^3 \times S^1$ Structure

4.1 Spatial Geometry: S^3

The three spatial dimensions form a 3-sphere (S^3), not infinite flat space. This is the natural geometry for a holographic interior:

The 2D shell (topologically S^2) encodes the S^3 interior through holographic projection. This is analogous to how a 2D hologram encodes a 3D image. The S^3 geometry is compact (finite total volume) and without boundary—there is no "edge" of space, just as there is no edge on a sphere's surface.

4.2 Temporal Geometry: S^1

The time dimension forms a circle (S^1). This may seem counterintuitive—we don't experience cyclic time. However, several considerations support this structure:

The completion sequence has a natural periodicity related to the shell's finite structure. The factor of 2π appearing in $h = 2\pi\hbar$ reflects this circular geometry. We don't experience the full circle because we traverse only a small arc—our cosmic history is a segment of S^1 , not the complete loop.

4.3 The Product Structure

The full interior geometry is $S^3 \times S^1$ —a 3-sphere crossed with a circle. This is the unique compact 4-manifold that naturally emerges from holographic encoding on a 2D surface with an inward direction and a completion sequence.

The signature (3,1)—three spatial dimensions with positive metric contribution, one time dimension with negative metric contribution—follows from the distinct characters of these dimensions: spatial dimensions from geometry, time dimension from completion sequence.

5. Why Not Other Dimensionalities?

5.1 Why Not 2+1?

A 2+1 dimensional interior would require encoding on a 1D surface. This would occur if the parent universe had 2D space. While mathematically consistent, 1D encoding supports far less complexity—insufficient for the rich physics we observe. The holographic correspondence between boundary and bulk would yield only 2D space.

5.2 Why Not 4+1 or Higher?

A 4+1 dimensional interior would require either:

- (a) A 3D encoding surface (requiring 4D parent space), or
- (b) Additional structure beyond shell, inward direction, and completion sequence

Option (a) is possible—our universe could contain black holes whose interiors are 4+1 dimensional. But from a 2D shell, there is no geometric source for a fifth dimension. We have exhausted the available structure.

5.3 Why Not 3+0 or 3+2?

Could we have three spatial dimensions without time? No—the frozen emissions **MUST** complete. The completion sequence is not optional; it is inherent in the structure. Incomplete transactions cannot remain forever incomplete; their virtual connections seek resolution. This resolution sequence **IS** time.

Could we have two time dimensions? Only if there were two independent completion sequences. But all frozen emissions complete into the same interior; there is only one direction of completion, hence only one time dimension.

6. What Is Invariant, What Varies

6.1 Geometric Invariants

If this analysis is correct, certain features are INVARIANT across all black hole interiors (assuming 3D parent space):

- Dimensionality: always 3+1
- Topology: $S^3 \times S^1$ (or local approximations)
- Existence of quantum mechanics (transaction completion dynamics)
- Existence of h-like and c-like constants (minimum action, maximum propagation)
- Holographic information bounds

These are not parameters—they are structural necessities following from the geometry of holographic encoding.

6.2 Formation-Event Variants

What DOES vary between black hole interiors:

- Shell area → information capacity, scale ratio, effective constants
- Shell composition → particle spectrum, force content
- Collapse dynamics → initial conditions, symmetry properties
- Angular momentum → rotation, preferred directions

Different black holes have different areas, were formed from different collapsing matter, and have different spins. Their interiors would differ correspondingly. But all would be 3+1 dimensional.

7. Wormhole Topology and Emergent Dimension

7.1 No Space Between

A crucial point: there is no space "between" the wormholes. The wormhole network is not embedded in a pre-existing 4D space. The 4D space IS the network, experienced from inside by patterns traversing it.

This is analogous to how the internet has no physical space between nodes—only connections. Yet complex structure emerges from connection topology. Similarly, our 4D experience emerges from wormhole connection topology, not from an underlying spatial substrate.

7.2 Wormhole Interactions

Wormholes can interact where they share endpoints or have endpoints that are "near" on the shell. The concept of "near" on the shell provides a notion of spatial proximity in the interior. Two transactions with nearby shell endpoints interact more strongly—this is the origin of locality in physics.

The 3D character of spatial interaction follows from the 2D shell geometry. Points on a 2D surface have 2D neighborhoods, which holographically encode 3D spatial neighborhoods in the interior.

7.3 Time from Topology

The time dimension emerges differently—not from shell geometry but from completion ordering. This is why time is fundamentally different from space: space comes from where wormholes are; time comes from how they complete.

The metric signature (3,1) with opposite signs for space and time reflects this fundamental difference in origin. Space and time are not interchangeable; they arise from different aspects of the wormhole structure.

8. Implications

8.1 The End of Dimensional Mystery

If this argument is correct, the question "Why 3+1 dimensions?" has a definitive answer: because that is what holographic encoding on a 2D event horizon produces. The mystery dissolves into geometry.

This is not an anthropic argument. We are not saying "3+1 permits observers, so we observe 3+1." We are saying "3+1 is geometrically forced; no other possibility exists for a 2D encoding surface."

8.2 Hierarchy Consistency

In the nested universe hierarchy (parent contains our black hole, which may contain smaller black holes), dimensionality is preserved at each level—always 3+1. This provides consistency across the hierarchy.

What changes across levels is scale (information capacity) and potentially composition, not fundamental structure. A black hole within our universe would have a 3+1 dimensional interior, governed by its own constants derived from its own shell area.

8.3 Physics as Topology

This framework suggests that physics is fundamentally topological—the study of wormhole connection patterns—rather than the study of things in spacetime. Spacetime itself is emergent; the wormhole network is primary.

Forces, particles, fields—all may be features of wormhole topology rather than entities embedded in spacetime. This points toward a deeper reformulation of physics in topological terms.

9. Questions and Extensions

Several questions remain for further investigation:

Parent universe dimensionality: We have assumed the parent universe has 3D space. If this is also a black hole interior, that would follow necessarily. What lies at the top of the hierarchy, if anything?

2D parent universes: Could there be black holes in 2D parent spaces, producing 2+1 dimensional interiors? What would physics look like there?

The S^1 time structure: If time is truly circular (S^1), what determines the circumference? Why don't we observe temporal periodicity? Is the circle cosmologically large?

Mathematical formalization: The argument presented here is conceptual. A rigorous mathematical treatment—perhaps using category theory or algebraic topology—would strengthen the claims.

Experimental signatures: Does the topological origin of spacetime produce any observable effects that could distinguish this framework from others?

10. Conclusion

The dimensionality of spacetime—3 spatial dimensions plus 1 time dimension—is not a contingent fact about our universe. It is a geometric necessity following from holographic encoding on a 2D event horizon.

From the 2D shell, we get exactly 4 dimensions:

- 2D of shell position → 3D space via holography
- 1D of inward projection → spatial depth
- 1D of completion sequence → time

No more dimensions can emerge because the geometry provides no source for them. No fewer dimensions can exist because each emerges from an essential geometric element.

The universe is 3+1 dimensional not because it was designed that way, not because other dimensionalities are merely improbable, but because 3+1 is what holographic encoding on a 2D surface produces. The answer to "Why 3+1?" is simply: "Because 2D."

There is no block of spacetime. There are only endpoints and wormholes, connections and completions. What we call spacetime is how the connection topology appears to patterns propagating through it. The 3+1 structure is the topology's fingerprint—the inevitable shape of experience when reality is a network of wormholes projecting from a 2D surface into the patterns of its own completion.

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